

REMARKS

Claims 1 to 15, as amended, appear in this application for the Examiner's review and consideration. Claim 16 was canceled by a previous amendment without prejudice to Applicants' rights to file one or more continuation or divisional applications directed to the subject matter of that claim. The amendments are fully supported by the specification and claims as originally filed. In particular, support for the amendments of the claims to recite "wherein any solid added to the molten silicon is not a solid that generates a chloride containing gas when added to molten silicon" is found in the present specification at page 6, lines 21 to 25, page 8, lines 11 to 15 and 20 to 22, page 13, lines 27 to 37, and the examples at pages 21 to 26. Therefore, there is no issue of new matter.

Claims 1 to 15 stand rejected under 35 U.S.C. § 103(a), as allegedly being unpatentable over International Publication No. WO 89/02415 to Mellström et al. (Mellström), for the reasons set forth on pages 2 to 8 of the Office Action.

In response, Applicants submit that the presently claimed invention is directed to a method for removing boron from silicon. The presently claimed method comprises heating metal silicon containing boron as an impurity to a temperature ranging from the melting point of silicon to 2200°C to place it in a molten state. A solid comprising silicon dioxide and a solid comprising one or both of a carbonate of an alkali metal or a hydrate of a carbonate of an alkali metal are added into the molten silicon as to form a slag containing boron on the molten silicon, and remove the boron from the silicon. Any solid added to the molten silicon is not a solid that generates a chloride containing gas when added to molten silicon.

Contrary to the statement in the Office Action that the present specification does not provide a positive recitation of excluding any chloride producing solid other than chloride compounds, the amendment of the claims to change the recitation of "any solid added to the molten silicon is not a chloride that generates a chloride containing gas when added to molten silicon" to "any solid added to the molten silicon is not a solid that generates a chloride containing gas when added to molten silicon" is fully supported by the specification and claims, as originally filed.

For example, at page 8, lines 11 to 15, the present specification teaches that methods focusing on the use of chlorides that generate gases containing chlorides require considerable exhaust treatment becomes necessary, which is not preferable industrially. At page 8, lines 20 to 22, the present specification then teaches that the method of the invention solves the problems of the prior art. That will be understood by those skilled in the art as teaching that

the method of the invention solves the problem of the generation of chloride containing gases that occurs in prior art methods of removing boron from silicon.

It will be clear to those skilled in the art from the teaching of the present specification that the solution of that problem, as provided by the presently claimed method, requires excluding the addition of any solid that generates a chloride containing gas when added to molten silicon, as presently claimed.

Therefore, one of ordinary skill in the art would understand from the teaching of the present specification that the presently claimed method eliminates the emission of chloride containing gases during the removal of boron from silicon. To be within the scope of the invention, the addition of any solid that produces a chloride containing gas must be excluded from the method of the presently claimed invention.

In addition, at page 13, lines 27 and 28, the present specification teaches that only an extremely simple atmospheric melting furnace is required to practice the presently claimed method. One of ordinary skill in the art will understand that a simple atmospheric melting furnace cannot be used in any method of removing boron from silicon in which chloride containing gases are released, as such gases must be contained, and will not be contained by a simple atmospheric melting furnace. Where chloride containing gases are released, more than a simple atmospheric melting furnace is required to prevent the release of toxic chloride containing gases. Again, one of ordinary skill in the art will understand that the addition of any solid that produces a chloride containing gas must be excluded in the method of the presently claimed invention.

Moreover, the Examples provided on pages 22 to 26 of the present specification all disclose embodiments of the presently claimed method in which no solid that releases a chlorine containing gas upon heating is added to the molten silicon. Therefore, the present specification clearly supports a method in which any solid added to the molten silicon is not a solid that generates a chloride containing gas when added to molten silicon.

In contrast to the presently claimed method, as stated in the Office Action at page 3,

Mellstrom teaches solid chlorine compounds are used as the active slag-forming component. As solid chlorine compounds, chlorides of alkali and/or alkaline earth metals may be used, such as sodium, potassium or lithium chloride, or calcium, magnesium, barium or strontium chloride. Other conceivable solid chlorine compounds are hypo-chlorites, chlorates or perchlorates of alkali and/or alkaline earth metals. (emphasis in original)

It is Applicants understanding that that statement in the office is a citation to Mellström, page 2, lines 8 to 15. Throughout that reference, Mellström further discloses that solid chlorine containing compounds are required in the disclosed method. *See, e.g.*, Mellström, the Abstract and the Examples. In all the Examples, Mellström discloses the addition of a chlorine containing solid that will generate a chloride containing gas when added to molten silicon. Therefore, Mellström clearly discloses that solids that generate a chloride containing gas when added to molten silicon are an essential element in the disclosed method, as the chlorine compounds are used as the slag-forming component.

As Mellström clearly discloses that solids that generate a chloride containing gas when added to molten silicon are an essential element in the disclosed method, Mellström provides no reason for one of ordinary skill in the art to make and/or use the presently claimed method.

As previously discussed, the presently claimed method also provides unexpected results when compared to Mellström. With regard to the unexpected results provided by the presently claimed method, the Office Action states that a direct comparison cannot be made between the Examples of the present specification and the Examples of Mellström, as the initial amounts of boron in the Example are different, and the Examples of the present specification involve more refining steps. Those issues are addressed as follows:

In Example 1, Mellström discloses an experiment in which 1700 kg of silicon with a boron concentration of 13 ppmw (parts per million by weight) was refined twice. The total slag-forming agent had a total mass of 1400 kg or 82.35 percent of the mass of the silicon. The final boron content of the silicon was reduced to 6 ppmw. Thus, the amount of boron remaining in the silicon after the two refining steps of Example 1 of Mellström was 6/13 of the initial amount for a reduction of about 56 percent by mass.

By comparison, in Example 1 of the present specification, 15 kg of silicon having a boron concentration of 12 ppmw was refined twice. The total amount of slag material was 30 kg or twice the mass of the silicon. As a result of the two refining steps, the amount of boron in the silicon was reduced to 0.29 ppmw. That is the amount of boron remaining after two refining steps of the presently claimed method resulted in a reduction of over 97 percent by mass.

It will be clear to one of ordinary skill in the art that the absolute amount of silicon is irrelevant. It is the amount of slag relative to the amount of silicon, i.e., the slag/silicon ratio, and the percent reduction of boron that are important. To obtain values that allow a direct comparison of the Examples provided by Mellström and the Examples of the present

specification, the values disclosed in Example 1 of Mellström can be converted to values that correspond to the amounts of boron and slag in the Examples of the present specification. That will allow the reduction of boron in the Examples disclosed by Mellström to be directly compared to the Examples provided in the present specification.

The first step is to assume that the initial boron content of a silicon sample is 12 ppmw. The reduction in the relative amount of boron with the method disclosed by Mellström using the amount of slag used in the Examples of the present specification can then be calculated.

Then, a slag ratio equivalent to the slag ratio of the Example of the present specification must be assumed. The slag ratio, i.e., slag/silicon, disclosed by Mellström is about half that of the Example of the present specification. For the sake of argument the reduction in the method of Mellström is taken to be twice that disclosed in Example 1 of that reference, which is equivalent to a reduction to $(6/13)^2$ or $6/13 \times 6/13$ of the initial amount of boron.

Next, the amount of slag disclosed by Mellström is only 82.85 percent of the mass of silicon treated with the method of Mellström. That is, Mellström discloses an amount of slag that is 17.65 mass percent less than the amount used in the Example of the present specification. That results in a correction factor of 0.8235. Thus, the final amount of boron obtained with the method of Mellström using the concentration of boron and the amount of slag used in the Example of the present specification can be obtained as follows:

$$12 \times 6/13 \times 6/13 \times 0.8235 = 2.1 \text{ ppmw.}$$

That indicates that, using the method disclosed by Mellström with the amount of silicon, boron, and slag disclosed in the present specification, the reduction in boron is 82.5 percent, which is significantly less than the 97 percent reduction obtained with the presently claimed method. In other words, the method disclosed by Mellström will reduce a 12 ppmw concentration to 2.1 ppmw, which is over seven times greater than the 0.29 ppmw obtained with the presently claimed method after being treated with the same amount of slag the same number of times.

Similarly, in Example 2, Mellström applies a single treatment of the disclosed method to a sample of silicon containing 17 ppmw using an amount of slag equal to about 91.7 percent of the weight of the silicon, and obtains silicon containing 5 ppmw boron. To calculate the reduction obtained by Mellström with values corresponding to the presently claimed method as disclosed in the Examples of the present specification requires the following equation, which corresponds to the equation above.

$$12 \times 5/17 \times 5/17 \times 0.917 = 0.95 \text{ ppmw}$$

Thus, the amount of boron remaining in the silicon with the method disclosed by Mellström is over three times greater than the amount obtained with the presently claimed method.

However, the above equations are based on the assumption that the percentage reduction in boron is the same each time the silicon is treated. That assumption is clearly not correct. The reduction of boron in mass percent is significantly less in each iteration of a method of removing boron. For example, in Example 1 of the present specification, the first iteration of the presently claimed method reduces a 12 ppmw boron content to 1.7 ppmw, which corresponds to an 85.8 mass percent reduction in the amount of boron. The second iteration of the presently claimed method reduces the boron content of 1.7 ppmw to 0.29 ppmw. That corresponds to an 82.9 mass percent reduction in the amount of boron.

Therefore, the two calculations of the reduction in boron that can be obtained with the method of Mellström provided values that are lower than one of ordinary skill in the art would expect to obtain. That is, in Example 1, Mellström discloses that 6/13 of the initial boron content remains after the treatment. One of ordinary skill in the art will understand that, after a second treatment, the amount of boron will be greater than 6/13 x 6/13 of the initial boron content, and, thus, will be greater than the 2.1 ppmw calculated above.

Similarly, in Example 2, Mellström discloses that 5/17 of the initial boron content remains after a single treatment. One of ordinary skill in the art will understand that, after a second treatment, the amount of boron will be greater than 5/17 x 5/17 of the initial boron content, and, thus, will be greater than the 0.95 ppmw calculated above.

Clearly, the presently claimed method provides unexpectedly superior results to those provided by the method disclosed by Mellström.

Therefore, as Mellström fails to provide any reason to one of ordinary skill in the art to practice the presently claimed method in which any solid added to the molten silicon is not a solid that generates a chloride containing gas when added to molten silicon, and the presently claimed method provides unexpected results compared to method disclosed by Mellström, the present claims are not obvious over that reference. Accordingly, it is respectfully requested that the Examiner withdraw the rejection of claims 1 to 15 under 35 U.S.C. § 103(a) over Mellström.

Applicants thus submit that the entire application is now in condition for allowance, an early notice of which would be appreciated. Should the Examiner not agree with Applicants' position, a personal or telephonic interview is respectfully requested to discuss

any remaining issues prior to the issuance of a further Office Action, and to expedite the allowance of the application.

No fee is believed to be due for the filing of this Amendment. Should any fees be due, however, please charge such fees to Deposit Account No. 11-0600.

Respectfully submitted,

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